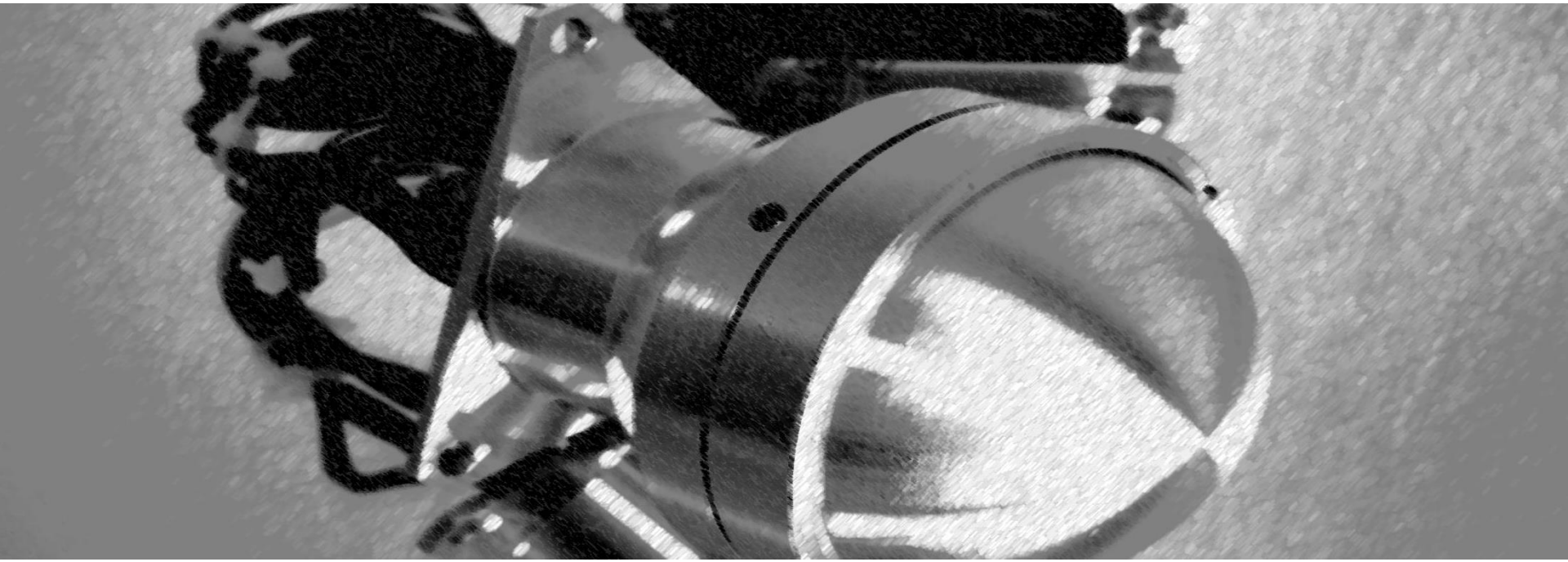
In-Orbit Demonstration of a MEMS-based Micropropulsion System for Cubesats



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Outline

- Introduction
- Propulsion for micro/nanosatellites
  - Propulsion module designs
  - Closed loop thrust control
- Flight data from TW-1 mission
- Next steps
- Concluding remark
- *Swedish lesson?*

MEMS – MicroElectroMechanical Systems

- **MEMS enables small sizes**
  - *µm feature sizes*
- **MEMS enables batch fabrication**
- **MEMS enables on-chip integration**
  - *Nozzles, sensors, actuators…*

➡ ***"Small & smart components in large numbers"***

Blue Bottle Fly (Calliphora vomitoria)

NanoSpace Idea:
To provide products for the space market based on novel MEMS technology

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NanoSpace Products

MEMS based Micropropulsion System

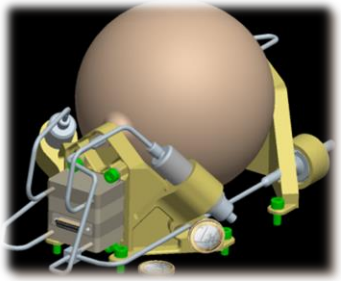
• Miniaturized propulsion system for precision control of satellites

Xenon Flow Control

• Miniaturized components for flow control in electric propulsion systems

Propellant Gauging System

• A propellant gauging system for telecommunication satellites



Individual sensors and actuators

- Flow control valves
- Isolation and safety valves
- Filters
- Sensors
- *Terrestrial applications*

ISO 9001:2008 certified
Airbus approved supplier

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Propulsion for micro-/nanosatellites

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Propulsion Modules for Cubesats

- 3U cubesat propulsion module: in orbit since Sept 2015
- 6U cubesat propulsion module: first flight 2017
- Custom designs: *Tank size, number and orientation of thrusters, etc*

Complete system:

- Propellant tank and feed system including filters, isolation valves, sensors, heaters
- Thrusters with proportional control
- Control and interface electronics to the satellite platform

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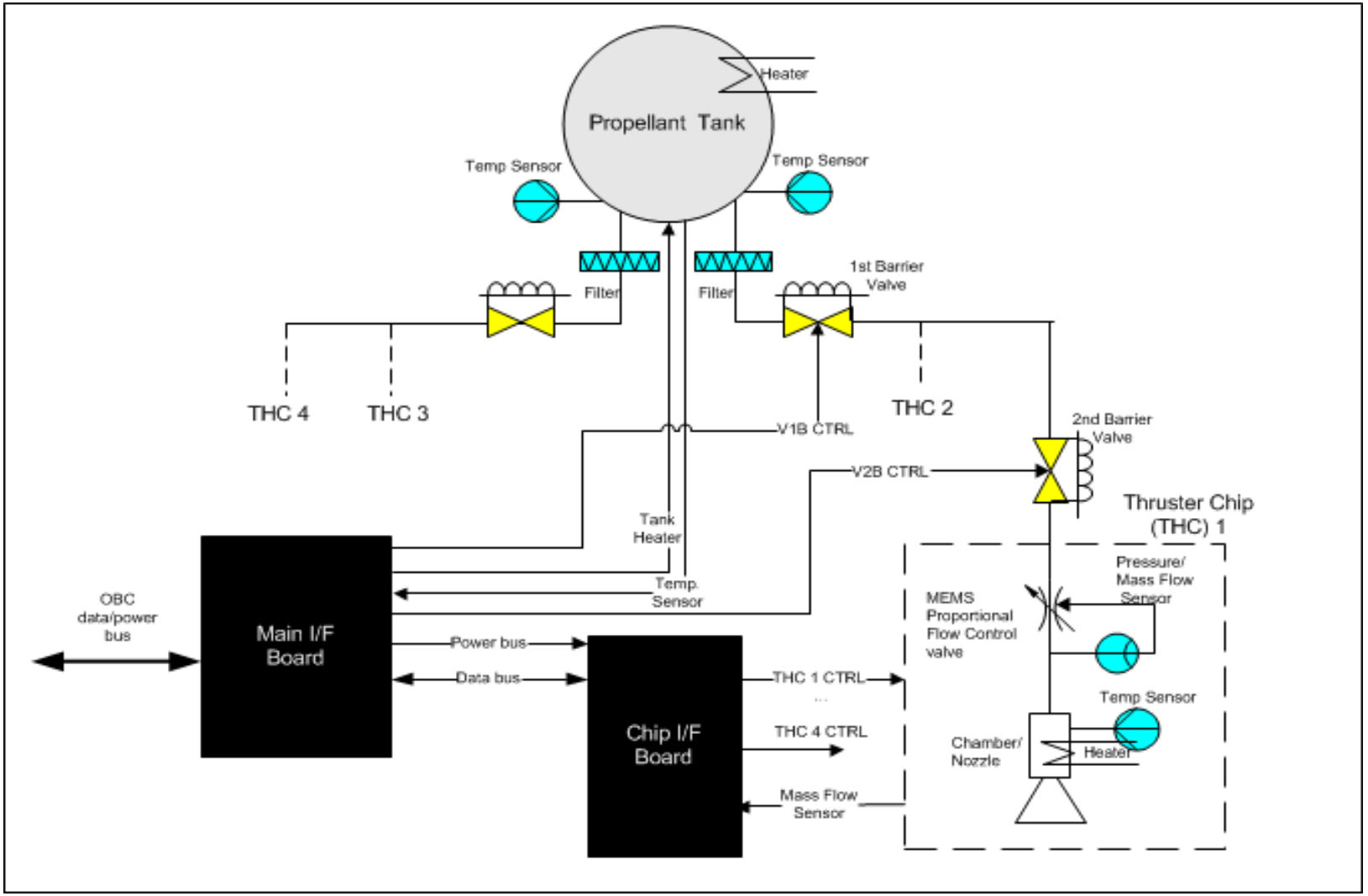
3U Design – System Schematic



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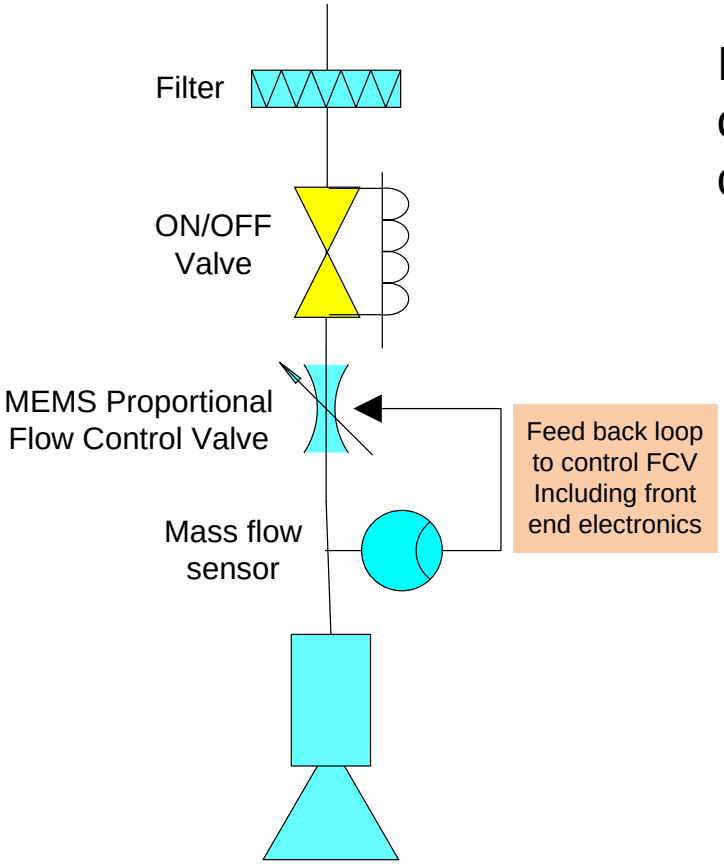
The 3U CubeSat propulsion module

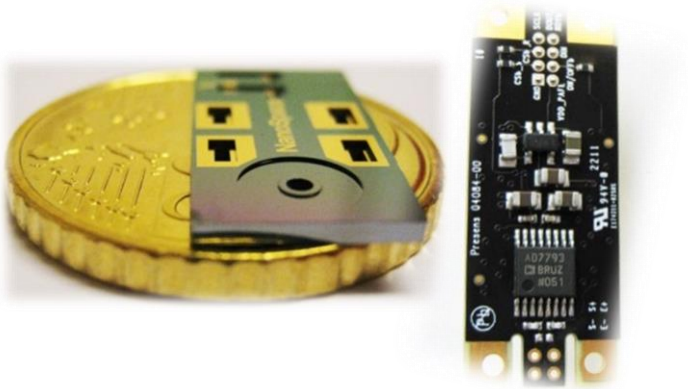
- Four 1mN thrusters with closed loop thrust control
- Thrust resolution: <10µN
- Propellant: Butane
- Total impulse: 40Ns
- Size: 10 x 10 x (3-5) cm
- Mass: 300/350 g (Dry/Wet)
- Operating pressure: 2-5 bar
- Power consumption: 2 W (average, operating)
- Electrical interface:
  - *Power: 12V, 3.3V*
  - *Communication: CAN / I2C*
- Mechanical interface:
  - *Conforms to 4x M3 (position according to PC/104 spec.)*

Closed-Loop Thrust Control



Integrated mass flow sensor provides control signal to the proportional flow control valve

⇒ Closed loop thrust control



Thruster chip and front end electronics

Figure: Schematic view of a complete closed loop control thruster. ON/OFF valve in conventional technology, the rest in MEMS.

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Closed-Loop Thrust Control
– *Unlike most other*

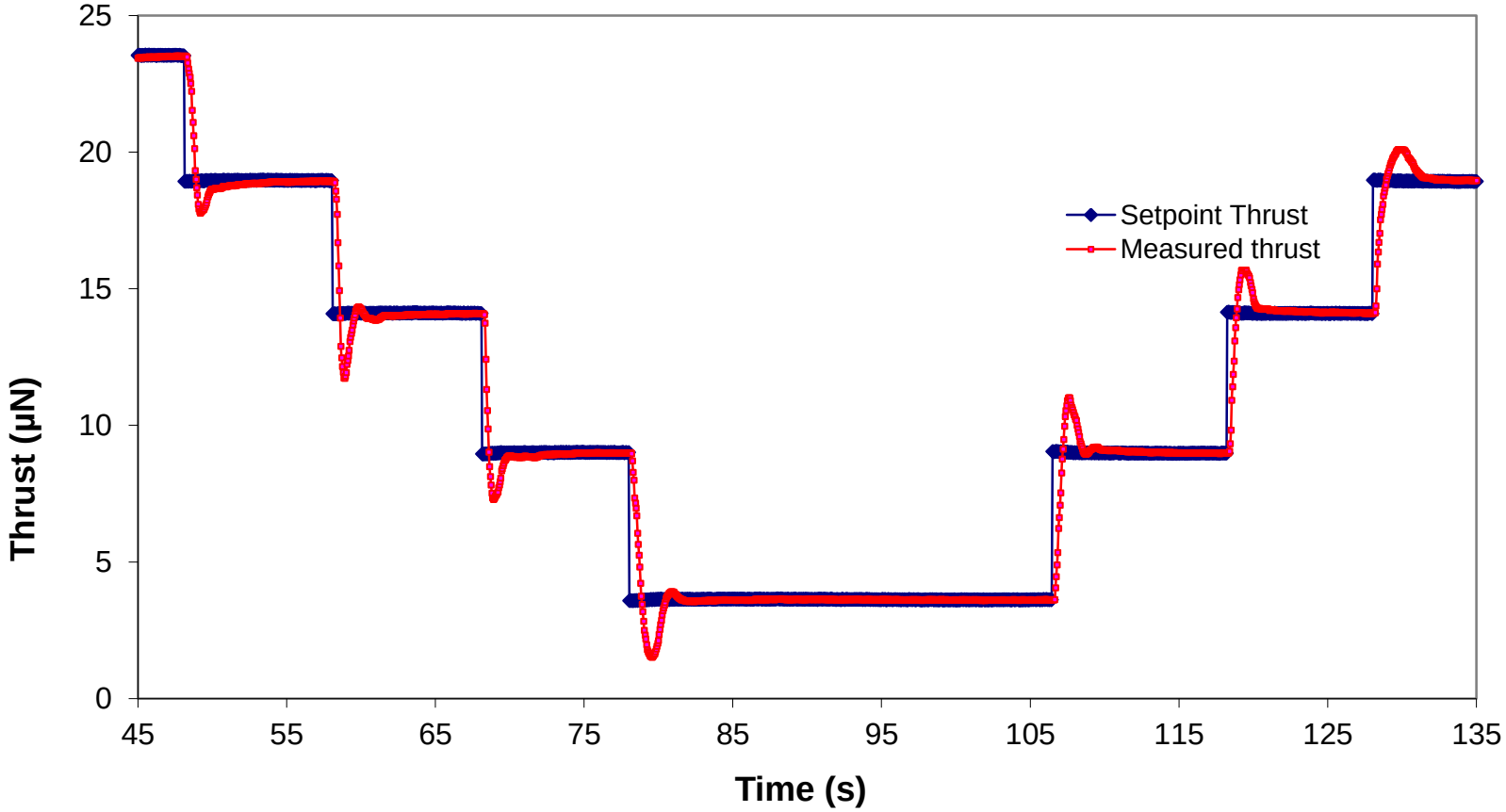

Figure: Test result of a MEMS valve operating in closed loop control mode showing the the thrust response to commanded steps of 5 µN.

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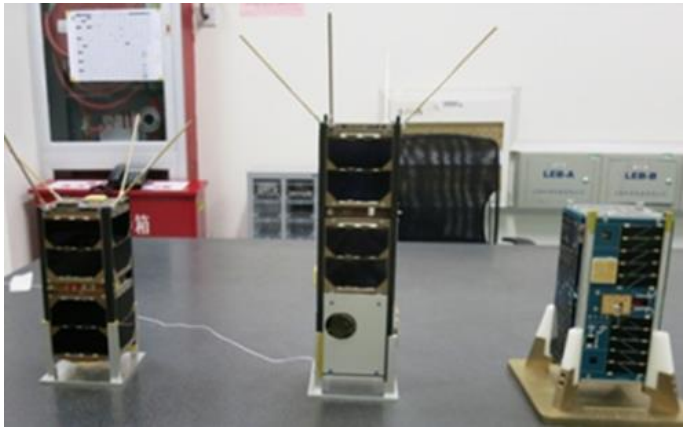
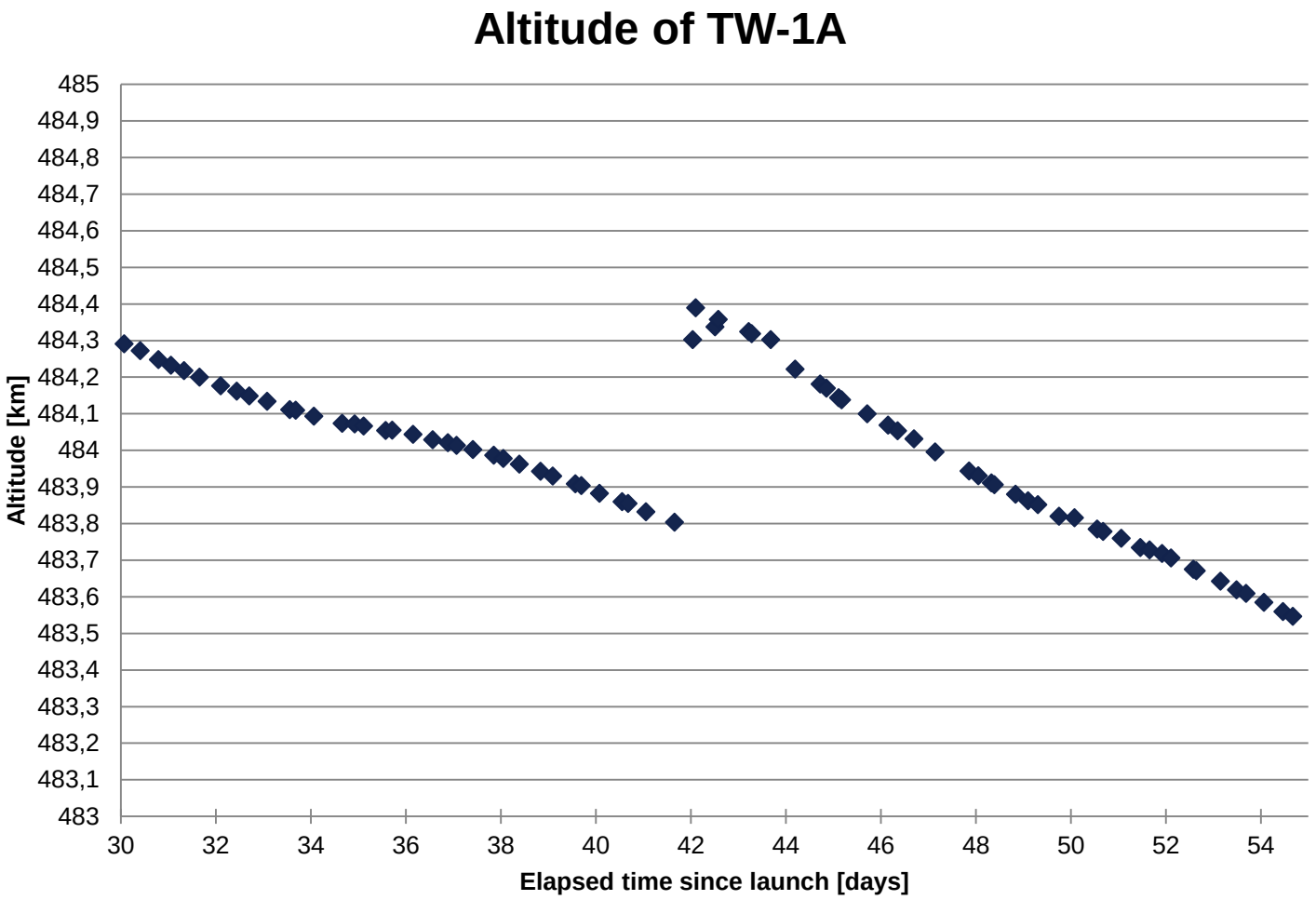
In Orbit Demonstration on TW-1

- TW-1 constellation (also named STU-2)
  - Two 2U + one 3U cubesats
  - Built by Shanghai Engineering Centre for Microsatellites (SECM)
  - Launched on September 25th 2015 with the new LM-11 to 480 km SSO
- Propulsion to be used for along track formation
  - Control relative distance between 1 and 1500 km
- Payloads
  - AIS, ADS-B, GPS/BD-2, ISL (S-band),
  - Camera
- Mission objectives
  - Ad-hoc intersatellite networking
  - Ship and polar ice monitoring
  - Payload and propulsion demonstration



Orbital data of TW-1 mission



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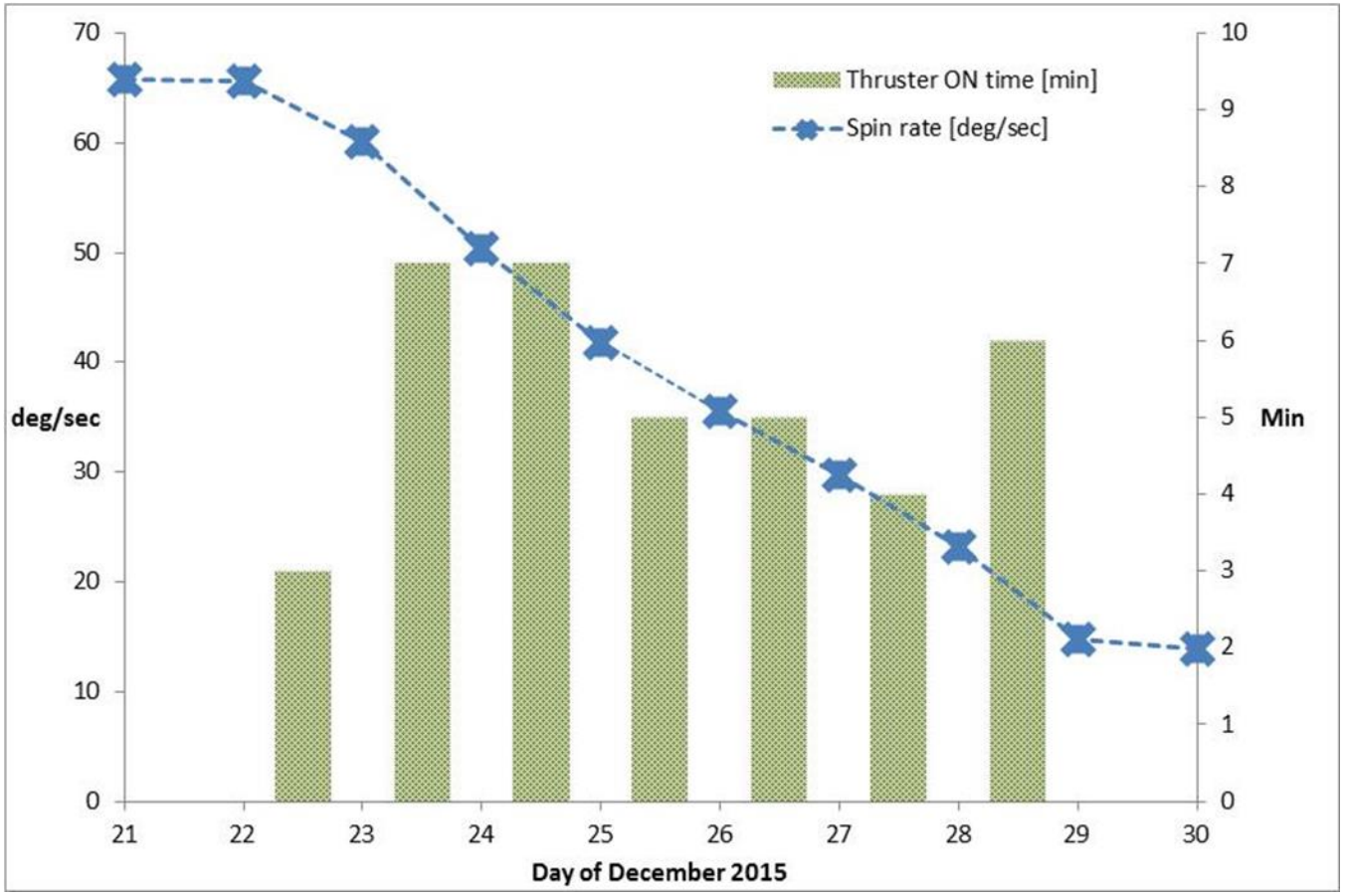
De-spinning the satellite



.. by ”live” operation during passage

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Next steps

- TW-1 mission continues:
  - *10 months+ in orbit, plenty of propellant left*
- Multiple flights coming up for the 3U propulsion module the coming years:
  - *2017 – 3U cubesat, University demo mission: ”MIST”*
  - *2017 – 3U cubesat precursor for ”Internet of Things” constellation*
  - *2018 – ESTCube-2: 3U cubesat, precursor for interplanetary electric solar sail missions ESTCube-3 and thereafter ESTCube-n*

ESTCube-2

- 2017 - First flight of the 6U propulsion

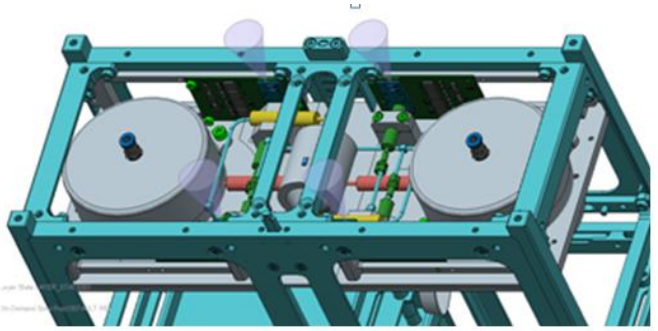
Upcoming 6U flight: GOMX-4B

- Our propulsion system is onboard on of the 6U cubesats in the tandem mission GOMX-4
- Propulsion needed to demonstrate formation deployment and control
- 6U design with heritage from flight demonstrated 3U design
  + "ESA style" verification process
- Project schedule:

  - PDR passed in May 2016

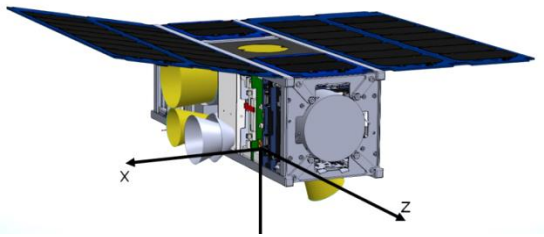
  - CDR in October 2016

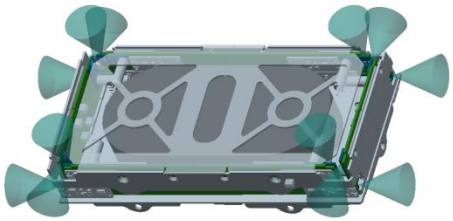
  - Launch in Q3 2017



Next steps - 2

- 2020 – AIM/PALS: Two 3U cubesats on Asteriod Impact Mission, 6DOF is key
- 2018 - ESA qualification of a generic propulsion module for advanced cubesat missions
  (12 thrusters x 10mN, 500g, 375Ns, 6W)
- Thruster upscaling – for larger cubesats and microsats
  - *10-50 mN butane thrusters*
  - *Distributed thruster architecture*





-> All together we forsee ~100 cubesats with propulsion the coming 4-5 years

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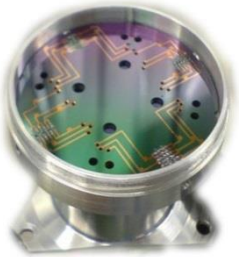
Concluding remark

Propulsion is here

- also for the micro/nano satellites

Come see our **SMÖRGÅSBORD** [ˈsmœrgɔsˌbuːd] of **miniaturized components** in **SSCs boot 26-27**



Isolation valves, flow control devices, filters, thrusters

Xenon flow control module

CubeSat propulsion module

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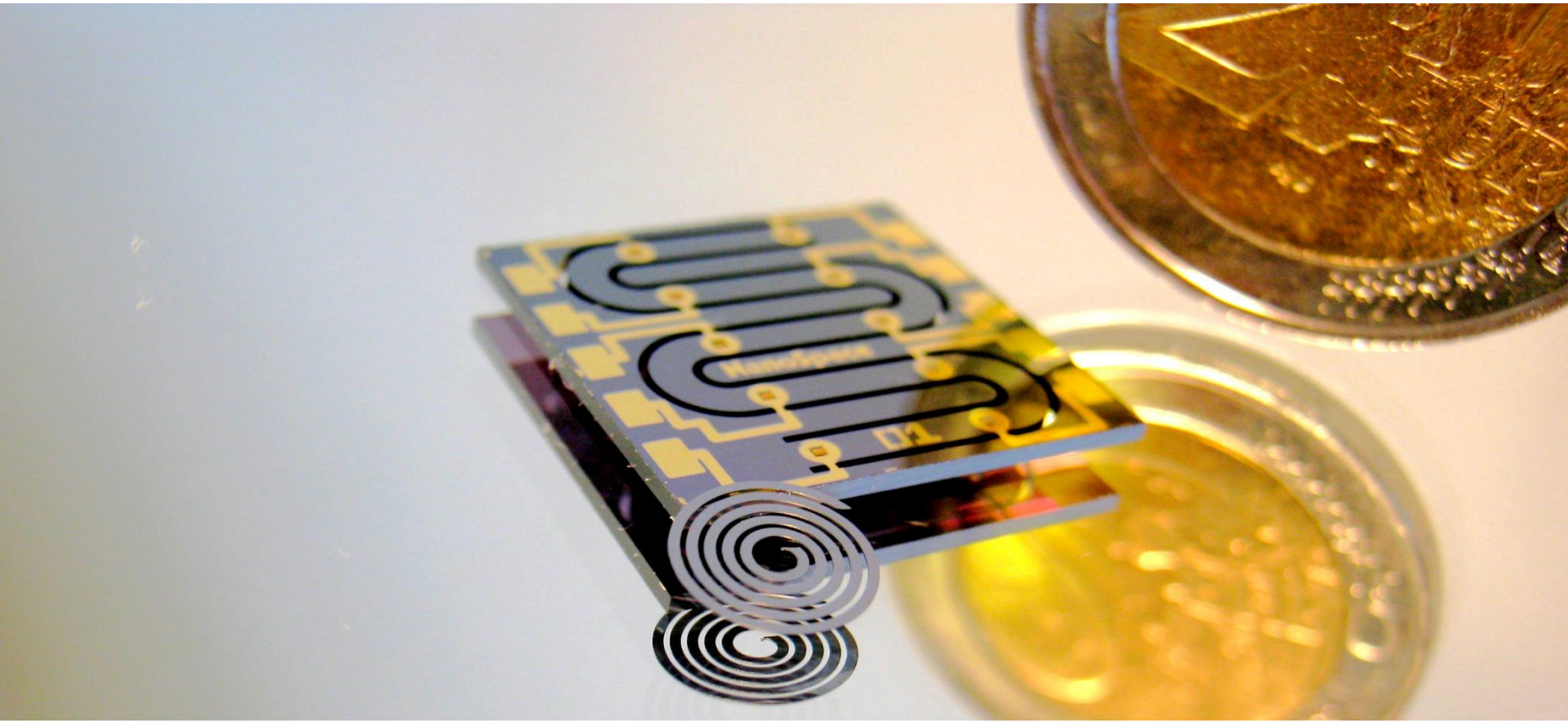
Thank you for your attention!



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